Summary of Final Report, BD545-09
March 2006

CRACK CONTROL IN TOPPINGS FOR PRECAST FLAT SLAB BRIDGE DECK CONSTRUCTION

PROBLEM STATEMENT

Precast flat slab bridge construction provides a convenient and economical option for short-span bridges. These bridges are constructed by erecting precast slabs that span from pile bent to pile bent. The slabs form a solid base that acts as a stay-in-place (SIP) form for a cast-in-place deck. Longitudinal reinforcement already in place in the precast slab acts as the primary reinforcement for the span. However, it is necessary to place a transverse layer of reinforcement in the cast-in-place portion of the slab. This reinforcement, combined with proper concrete curing, is intended to provide crack control and lateral transfer of shear between panels. This top reinforcement is needed to control shrinkage cracking that occurs during the first few months after the concrete placement. In addition, stresses can develop due to thermal changes in the deck. Improper steel placement combined with less than optimal curing can cause significant cracking to occur in the deck. This cracking usually concentrates at the precast slab joints that run parallel to the roadway.

OBJECTIVES

The objective of this research project was to evaluate techniques for improving crack control in toppings for precast panels. The research focused on the effectiveness, ease of implementation, and application of the techniques, as well as on their effect on the labor and construction cost of the bridge. Commercially available treatments for crack control were reviewed, several of which were selected for further testing, including steel fibers, synthetic fibers, steel/synthetic fiber blend, carbon fiber reinforced composite (CFRP) grid, and shrinkage reducing admixture.

FINDINGS AND CONCLUSIONS

Four full-scale bridge superstructures were constructed to evaluate the crack control treatments. Each superstructure was composed of three 4 ft. x 30 ft. precast flat slabs with a 6-in. thick concrete topping. The precast slabs were constructed off-site by a prestressed concrete manufacturer. The treatments were each incorporated into a standard Florida Department of Transportation (FDOT) approved concrete mixture and cast on-site by FDOT Structures Laboratory staff. Cylinder tests were conducted for compressive strength, tensile strength, and modulus of elasticity. The cracking performance of the treatments was evaluated using a restrained ring test. The toppings were visually monitored for 30 weeks for crack formation. Plastic shrinkage cracks were visible in the control topping as well as in the toppings with the shrinkage reducing admixture (SRA) and CFRP grid (GRD). No further cracking, however, formed during the monitoring period.

In addition to the restrained ring test, and in order to provide a relative measure of the treatments under transverse tensile stress, load tests were performed on each of the specimens. The bearing pads were relocated so that the self-weight of the specimens caused flexural tensile stresses to form in the topping over the precast joints. Additional weight was needed to generate cracking in some of the specimens.

The following are among the findings and conclusions:

- Insufficient tensile stresses from drying shrinkage were generated in the toppings to induce cracking. One possible explanation is that the placement and curing were conducted under relatively ideal conditions, which contributed to the lower shrinkage strains. Another possibility is that the slabs were constructed in the very humid summer months, with ambient humidity at 80% or above, which would provide curing conditions better than those that might occur in the dryer winter months. The latter explanation is supported by the fact that the restrained ring specimens did not crack until after the relative humidity dropped below 70 percent. Yet another possibility is that the test specimens were not as wide as those generally used in bridges where reflective cracking has been observed. It is suspected that a wider cross-section would lead to more lateral restraint in the center of the cross-section.
- Modulus of elasticity and tensile strength were unaffected by the crack control treatments used in this research.
- In both the restrained ring test and the load test, the all-steel fiber (STL) topping provided nearly an order of magnitude reduction in crack widths.
- The CFRP grid (GRD) topping reduced the crack widths in the load test by a factor of two.
- In the restrained ring test, the blended fiber (BND) and all-synthetic fiber (SYN) toppings reduced crack widths by a factor of four. In the load test, BND and SYN toppings reduced the crack widths by a factor of two.
- The topping with a shrinkage reducing admixture (SRA) reduced crack widths in the restrained shrinkage test by a factor of seven.

As with any concrete construction, proper mixing, transporting, placement, and curing are crucial to a successful finished product. Therefore, while the all-steel fiber system (STL) was shown to be the most effective technique for reducing crack widths under load and in the restrained ring test, it should be noted that it was also rated as the most difficult to place, vibrate, and finish (followed by the all-synthetic fibers and the blended fibers). Directly adding fiber to an FDOT-approved mix without accounting for the reduction in workability may increase the temptation to add water at the job site because of the reduced workability. When fiber additives are being considered for use in toppings, it is recommended that trial mixes be prepared to ensure that adequate workability will be available without the addition of water. Indeed, fiber-reinforced concrete with fiber volumes, such as those used for the steel (STL) and synthetic (SYN) fibers specimens, should incorporate a high-range-water reducer to improve workability.

BENEFITS

The value of this research is that it has shown that a precast flat slab bridge deck system (for the width and configuration tested) can be constructed without reflective cracking, even when additives are not used—although the use of additives would provide additional assurance. The result is long-term cost savings through improved durability and longevity of the structure.

This research was conducted by H. R. (Trey) Hamilton, III, Ph.D., P.E., of the University of Florida. For more information, contact Marc Ansley, P.E., Project Manager, at (850) 414-4291, marc.ansley@dot.state.fl.us.